THE APPLICATION OF AUSTRALIAN EXPERIENCE WITH SURFACE DISPOSAL OF PASTE AND THICKENED TAILINGS TO THE OIL SANDS INDUSTRY

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ABSTRACT

The concept of thickened tailings "stacking" as a means of surface disposal of mine tailings, first introduced by Eli Robinsky in the mid 1970s as an alternative to storing tailings in impoundments behind embankments, has come a long way. Australia has been a leader in research and development of the method. From an initial application in base metals tailings, the technique has now been successfully implemented (19 existing Australian operations) for a wide range of other tailings types, including bauxite, mineral sands, gold, coal and diamonds.

The authors present a brief overview of the Australian experience to date and provide insights into the application of this technology in the oil sands industry. Experience with mineral sands tailings, is particularly relevant because of the similarity in mineral composition for both the coarse and fine fractions. The current focus with mineral sands is on co-disposal of the sand and clay fractions. These present materials handling, segregation, and consolidation problems, as well as questions relating to long term behaviour and rehabilitation. The paper will discuss these issues by way of both theory and practical example.

INTRODUCTION

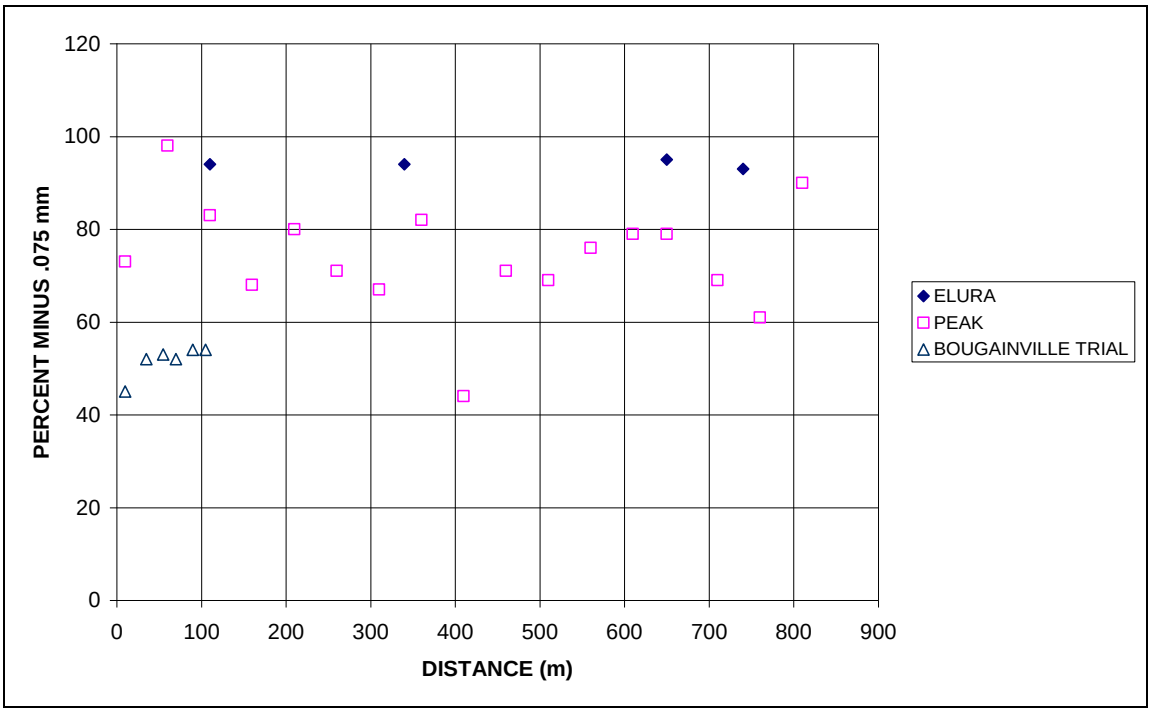
The most common form of tailings disposal in the mining industry remains surface disposal into engineering storage facilities. Paste backfill into underground mines has become increasingly popular, primarily as a means of support to mined out openings, but it can only take a proportion of the tailings tonnage, not the full amount. Backfilling open pits is superficially attractive but runs into difficulties with metals mining. Multiple discrete overbodies are needed since it is not possible to dispose of tailings and mine simultaneously in the same space. And the mine planners and geologists must be sure that there is no potential ore resource beneath the bottom of the pit that would be quarantined as a result of pit backfilling. For large area surface mining, eg. Coal, mineral sands and oil sands, pit backfill is much more feasibile as mining advances, indeed in some jurisdictions in Australia it is mandated in the mineral sands industry.

Returning to surface disposal, the concept of "stacking" thickened tailings in a low conical pile on flat ground, referred to in this paper as central thickened discharge (CTD), was introduced to the mining industry by Eli Robinsky in Canada in the 1970's at Kidd Creek at Timmins in Ontario (Robinsky, 1975). The operation is still going strong. The second application was in Australia at the Elura zinc/lead mine at Cobar in New South Wales in 1981. This operation is also still going strong. It is the application of the key operating principles of this concept, and the experience gained in many subsequent projects, primarily in Australia, to the oil sands industry that is the subject of this paper.

2. Operating Principles for Thickened Tailings Stacking

The key parameter for tailings to be disposed of successfully by stacking is that the slurry should be non-segregating. In other words, the coarse and find fractions should be deposited together on the beach in consistent proportions regardless of the distance from the discharge point. This is demonstrated in the plot on Figure 1 which shows the percent minus 75 microns in samples at varying distances down the beach for three projects, Elura mine already mentioned, the Peak gold mine also at Cobar in New South Wales, and for a large scale stacking trial undertaken at Bongainville copper in the 1980's.

Figure 1 Particle size distribution versus distance from discharge (Williams, 2000)



Scatter in the points can be seen, but no overall trend for progressive hydraulic sorting. An important consequence of non-segregation is that for a given slurry percent solids, a uniform, planar beach slope will be formed. Figure 2 shows the comparative cross-sections for CTD and down-valley discharge (DVD) stacks with planar and concave profiles. The loss of storage capacity in the stack for a given head-of-beach and area is apparent.

The advantages of stacked thickened tailings over conventional impoundments are:-

- Lower capital cost in the absence of the need for extensive embankment construction.
- Lower operating cost in the absence of the need for continuous spigot discharge management.

Both cost items are, needless to say, site specific and can vary.

- Reduced risk as a result of the elimination, or at least minimisation of embankments.
- Reduced scope for contaminated seepage to groundwater.
- Water savings.
- The relatively flat beach slopes create a landform that is easier to stabilise after closure and is generally more in keeping with the natural terrain. Immediate access onto the beach is usually possible after closure which facilitates the spreading of cover materials.

An offsetting disadvantage is the likelihood that the footprint area of the disposal stack will be greater than an equivalent impoundment storage. This will depend on beach slope and topography.

3. History of Stacked Tailings Schemes

The table on the following pages (Table 1) represents a catalogue of thickened and paste tailings disposal schemes that the authors have compiled, mostly from published data, including papers and case studies presented at Paste conferences. The list covers full scale schemes only, and is limited to surface disposal including in-pit disposal. Underground backfill schemes

are not included. It is not imagined that the list is complete and the authors would welcome hearing of additional examples that readers may be able to supply.

Comments on the list as presented are as follows:

- Schemes are located in eight countries but 19 of the 32 schemes, i.e. 60%, are in Australia.
- The growth in the number of thickened tailings and paste surface disposal schemes with time is plotted on Figure 3.

Figure 3 Number of surface disposal schemes with time

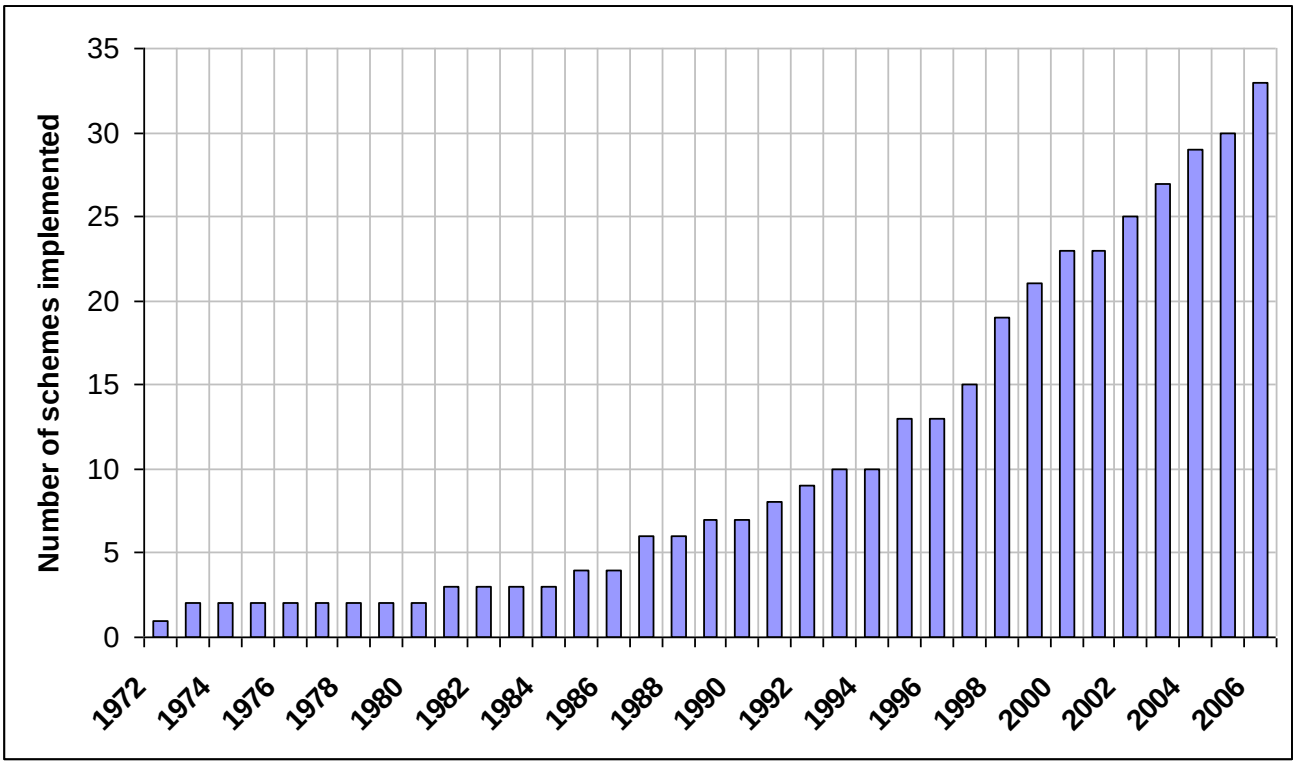


Table 1 Listing of thickened and paste tailings schemes implemented world-wide

Mine Site	Location	Ore Type	Start Year	Status	Typical Rate	Thickener Details				Floc. Rate	Tailings slurry properties		Disposal Scheme	Beach Slope Achieved		Reference
						Type	No.	Dia.	Unit Load		SG	Conc.		Max	Range or Typical	
					Mtpa			m	t/m².hr	g/t		% w/w		%	%	
Surface disposal																
Kidd Creek	Ontario, Canada	Copper/zinc	1973	Active	2.92	HC	1	35	0.37	20 to 25		63	CTD	2.5	1.5	Lord,2003
Elura	NSW, Australia	Zinc	1981	Active	1.0							60	CTD Segmented	1.7		Williams & Seddon, 1999
Argyle	WA, Australia	Diamond	1985	Deactivated	3.3-6.5							72(??)	CTD Segmented	10 target		McMahon et al, 1996
Peak[1]	NSW, Australia	Gold	1992	Active	0.4	HR	1	8	0.97	10 to 15		55-62	CTD	2.5 +	1.5-2.0	Williams & Seddon, 1999; ATC Internal
Union Reefs	NT, Australia	Gold	1995	Closed 2001	2.0-3.0	HR	1					<55	DVD	0.9		Williams & Seddon, 2003
McArthur River	NT, Australia	Lead	1995	Active	2.4							60	CTD	1.0		Williams & Seddon, 1999
Cluff Lake	Saskatchewan, Canada	Uranium	1995	Closed 2002	0.32	HD	1	26	0.02		2.7	52	DVD	3.0		Lord,2003
Ernest Henry	Qld, Australia	Copper	1997	Active	7.0	HC	1	70	0.22		3.3	75	CTD	1.1		Williams & Seddon, 1999
Mount Keith	WA, Australia	Nickel	1997	Active	10.5							44	CTD Multiple	2.0		Williams & Seddon, 1999
	WA, Australia	Nickel	1997	Active	10.5							44	CTD Multiple	1.0		Bentel, Discussion Paste 2007
Blendevale (Pillara)	WA, Australia	Lead	1998	Closed	1.5							65	CTD	1.5		Williams & Seddon, 1999
Warkworth #2_ Redbank	NSW, Australia	Ash	1998	Active	0.1							70	Side hill	5.0		ATC Internal
Ekati	Canada	Diamond	1998	Active	1.6	HR DC	2	12	0.86		2.7	40	Surface	1.0	1	Lord,2003
Strathcona	Canada	Nickel	1998	Active	0.5	HR DC	1	10	0.23	20	2.9	45		1.5	1.25 - 1.5	Paste,2006
Century	Qld, Australia	Zinc	1999	Active	4.3	HR	1	45	0.33	32 to 38	2.8	52-58	DVD	1.0	0.6-1.0	Murphy,2006
Sunrise Dam	WA, Australia	Gold	2000	Active	3.6	HR	1	24	0.97	19		64	CTD	2.0	1.0-2.0	Williams & Seddon, 2004
Bulyanhulu	Tanzania	Gold	2000	Active	0.7	O								10 max		Landriaut, 2000
Myra Falls	Canada	Copper/zinc	2003	Active		P	1	25				65-68		3.0		Lord,2003
Kimberley CTP[2]	S.Africa	Diamond	2003	Active	8.6	P	5	15	0.36	<50		44-57	CTD	1.5	1	Houman & Johnson, 2003
Osborne	Qld, Australia	Copper / gold	2004	Active	1.34	HR	1	9	0.77		3.6	72-76	CTD	4.0	3	McPhail et al 2004, Brent and Dobb, 2006
Cobriza	Peru	Copper	2004	Active	1.8	P	1	14	0.43	35	3.73	77	DVD / side hill			V.Gonzales (D.O.E) Paste 2005, p261+
Miduk	Iran	Copper	2005	Active	4.8	P	4	16	0.73	25 to 30		63	DVD	2.5		ATC Internal
Ellendale E4 (TSF 2A)	WA, Australia	Diamond	2006	Active	3.7	HR	1	34	0.50	80	2.8	47-49	DVD			ATC Internal
Douglas	Vic, Australia	Mineral sands	2006	Active	2.0	HR	1				2.7		CTD			ATC Internal
Lone Mountain	USA (East)	Coal	1997	Closed 2007	0.8	Belt Press[3]	4	na	na	55	1.9	55	Trucked, side hill	2.0	1	Gupta & Johnson, Paste 2007
	USA (East)	Coal	2007		0.8	P[4]	1	15	0.55	55	1.9	55	DVD	2.0	1	Gupta & Johnson, Paste 2007

Thickeners	
HR	High Rate
HR DC	High Rate Deep Cone
HD	High Density
HC	High Compression
P	Paste
O	Other, refer notes

Disposal Schemes	
CTD	Central Thickened Discharge
DVD	Down Valley Discharge

Notes:

1. Max slope increased to 5% after switch to multi-spigot discharge
2. This is now planned to be a continuing surface disposal facility
3. Belt pressed to be decomissioned following commisioning of paste thickener
4. Westech Deep Bed paste thickener at TSF site
5. Knight Piesold, Patterson and Cooke etc
6. Thickened tailings used to cap in-pit deposit

Table 1 (cont.) **Listing of thickened and paste tailings schemes implemented worldwide**

Mine Site	Location	Ore Type	Start Year	Status	Typical Rate	Thickener Details				Floc. Rate	Tailings slurry properties		Disposal Scheme	Beach Slope Achieved		Reference
						Type	No.	Dia.	Unit Load		SG	Conc.		Max	Range or Typical	
					Mtpa			m	$t/m^2.hr$	g/t		% w/w		%	%	
In-Dump Disposal Schemes:																
La Quinua[5]	Peru	Gold	2008	Active ?	5.0	HR	1	32	0.76	11	2.8	69	DVD			Kerr et al., Paste 2007
In-Pit Disposal Schemes:																
EKAPA	S.Africa	Diamond	2002	Active	0.8	P	1	15	0.17	80-100	2.65	53-57	In Pit			Hohne et al, 2004
Pajingo	Australia	Gold	2002	Active	0.73	P	1	14	0.17			59-61	In Pit			Gregory, 2003
Hazelwood	Australia	Lignite Ash	2006	Active	0.2	HR	1	22	0.02	80-100	3.0	40-45	In Pit	low	<1%	New, Kearn & Sweeney, Paste 2007
Granites	Australia	Gold	1999	Closed[6]	0.2	HR	1				2.75	55-60	In Pit	2.0	n/a	ATC Internal
Red mud:																
Gove	NT, Australia	Bauxite	1972	Active									CTD			No details published
Vaudreuil (Jonquiere)	Canada	Bauxite	1987	Active	0.45	P	1	12	0.49		~3.0	45		4.0	3.0-4.0	Lord,2003
Alcoa Kwinana	WA, Australia	Bauxite	1989	Active	1.9	HC	1	50	0.12	60	~3.1	50	Dry Stacking	1.2	1.0 - 1.2	Cooling, 2000
Alcoa Pinjarra	WA, Australia	Bauxite	1987	Active	3.3	HC	1	90	0.06	50-80	~3.1	50	Dry Stacking	1.2	1.0 - 1.2	Cooling, 2000
Alcoa Wagerup	WA, Australia	Bauxite	1991	Active	2.2	HC	1	70	0.07	60	~3.1	50	Dry Stacking	1.2	1.0 - 1.2	Cooling, 2000
Aughinish	Ireland	Bauxite	1993	Active	1.7	O						63	CTD	2.7	1.5 - 2.7	Phil Newman, Paste 2006

Thickeners	
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- The distribution of schemes according to thickener type is shown in Table 2.
- Of the eight paste schemes, the bauxite stack at Vaudreuil in Canada dates from 1987, all of the remainder are from 2002 onwards.
- The range of mineral types is broad, as shown in Table 3.
- The distribution of the stack types is as shown in Table 4.

Table 2 Distribution of schemes according to thickener type

Thickener Type	Qty
High rate	9
High compression/high density, including Ecat	7
Paste	8
Other and belt press	3

Table 3 Range of mineral types

Mineral Type	Qty
Base metals – copper, zinc, lead and nickel	13
Gold	6
Uranium	1
Mineral sands	1
Diamonds	5
Coal	4
Bauxite	6

Table 4 Distribution of the stack types

Stack Type	Qty
CTD	14
DVD, including side-hill	9
In-pit	4
“Dry-stack” (red mud)	3